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Safeguards at LEU Fuel Fabrication Facilities

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Safeguards Science and
Technology N-1

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Introduction LEU Fuel Fabrication

- 39 plants
- 18 countries
- 23 000 tonnes Heavy Metal / year
- LWR fuel and others

Nominal Plant Capacity MTU/year					
LWR Uranium Oxide Fabrication Facilities Nominal Plant Capacities MTU/Year (1/1/2008)					
Country	Operator	Facility	Powder	Pellet	Assembly
Belgium	AREVA NP EU	Dessel	0	700	700
Brazil	INB-Resende	FCN Resende	165	120	240
China	Jianzhong	Jianzhong	400	400	450
France	AREVA NP EU	Romans	1200	820	820
Germany	AREVA NP EU	Lingen Fab	650	650	650
India	NFC-Hyderabad	Hyderabad	48	48	48
Japan	NFI-Kum/Tok	Kumatori	0	360	284
	MNF-TokaiMur	Tokai MNF	475	440	440
	NFI-Kum/Tok	Tokai NFI	0	250	250
Kazakhstan	JNF-Yokosuka	Yokosuka	0	620	750
	Kazatomprom	Ulba	3000	1000	0
Russia	TVEL-Ele/Nov	Elemash	1000	850	785
	TVEL-Ele/Nov	Novosibirsk	150	150	1000
South Korea	KNFC-Daejeon	Daejeon	600	600	600
Spain	ENUSA-Juzbad	Juzbado	0	400	400
Sweden	WestSE-Vas	Vasteras	530	530	400
U.S.A.	WestUS-Colum	Columbia Fab	1350	1500	1500
	AREVA NP US	Lynchburg	0	0	700
	AREVA NP US	Richland	1800	700	700
	GNF-Wilmington	Wilmington	1000	1100	1100
United Kingdom	WestUK-Sprin	Springfields	440	440	0
Total		MTU/Year	12808	11678	11817

Safeguards properties of LEU

- Low Enriched Uranium
- Significant Quantity $^{235}\text{U} = 75 \text{ kg}$
- @ 5% $^{235}\text{U} \rightarrow 1.5 \text{ tonnes U (indirect use material)}$
- (natural $\rightarrow 10 \text{ tonnes U (source material)}$)
- Timeliness: 1 year



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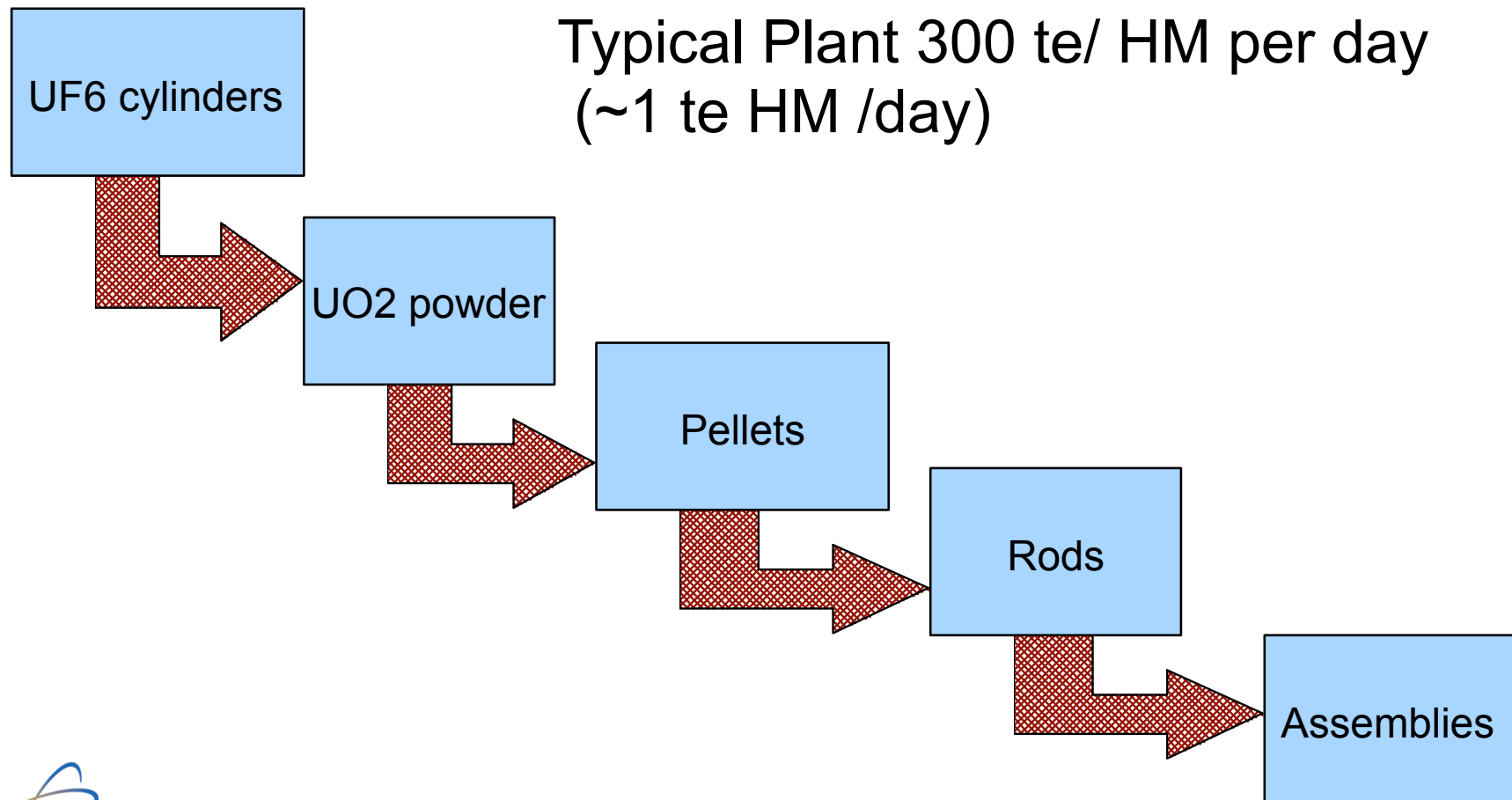
Safeguards on LEU Fabrication Plants

- Nuclear Materials Accountancy
- Annual PIV
- $MUF = \text{Starting Inventory} + \text{Receipts} - \text{Shipments} - \text{Ending Inventory}$
- Receipts = UF_6 cylinders
- Shipments = Assemblies + waste discards

Safeguards on LEU Fabrication Plants

- Check 20% of material flow
- Check Receipts
- Check Shipments
- Random Inspections (Mailboxes)
- Check that there is no $U > 20\% \text{ }^{235}\text{U}$
- Design Information

Basic Process



LEU Fabrication Feed and Product



UF6

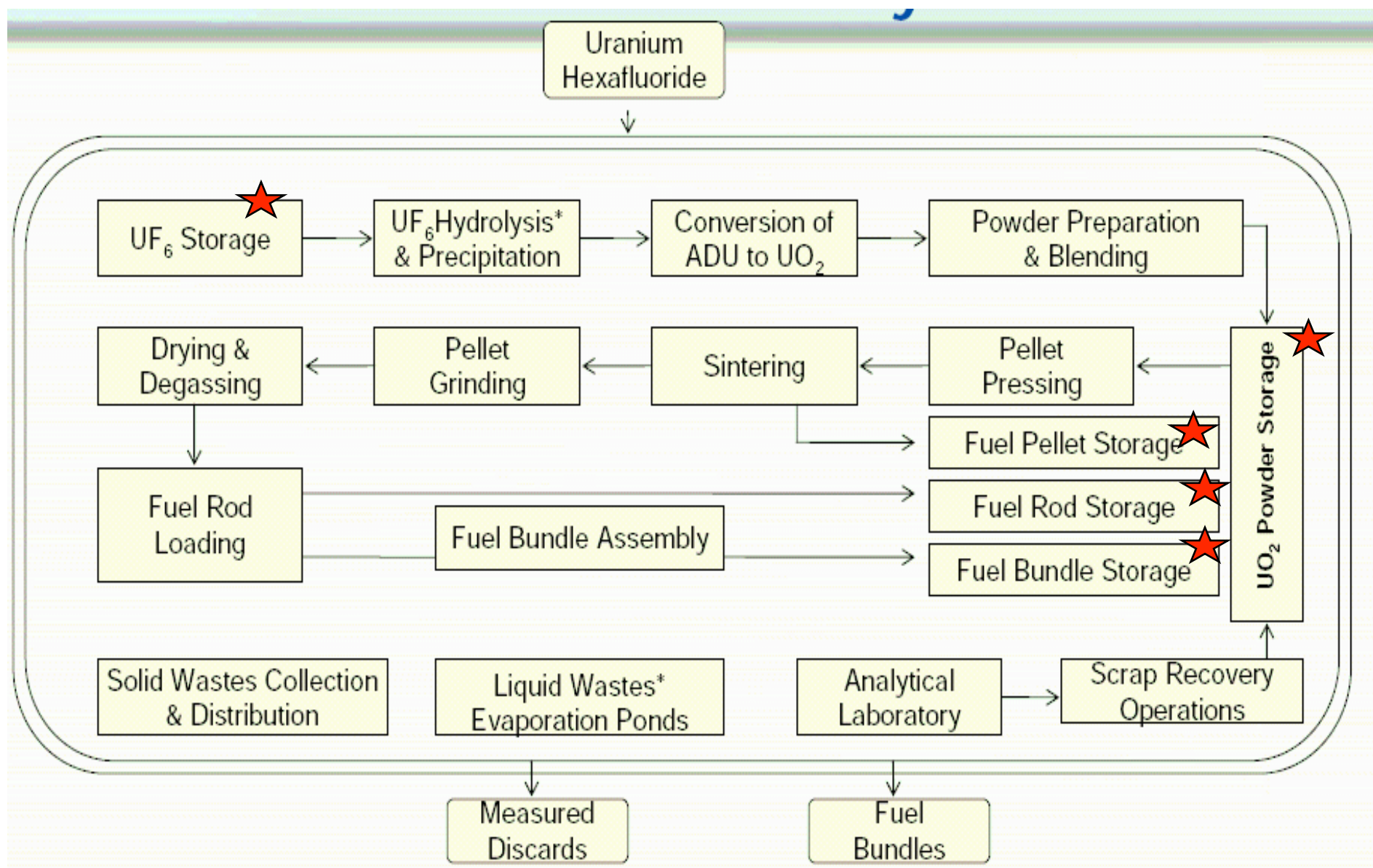


PWR assemblies

Fuel assembly casks

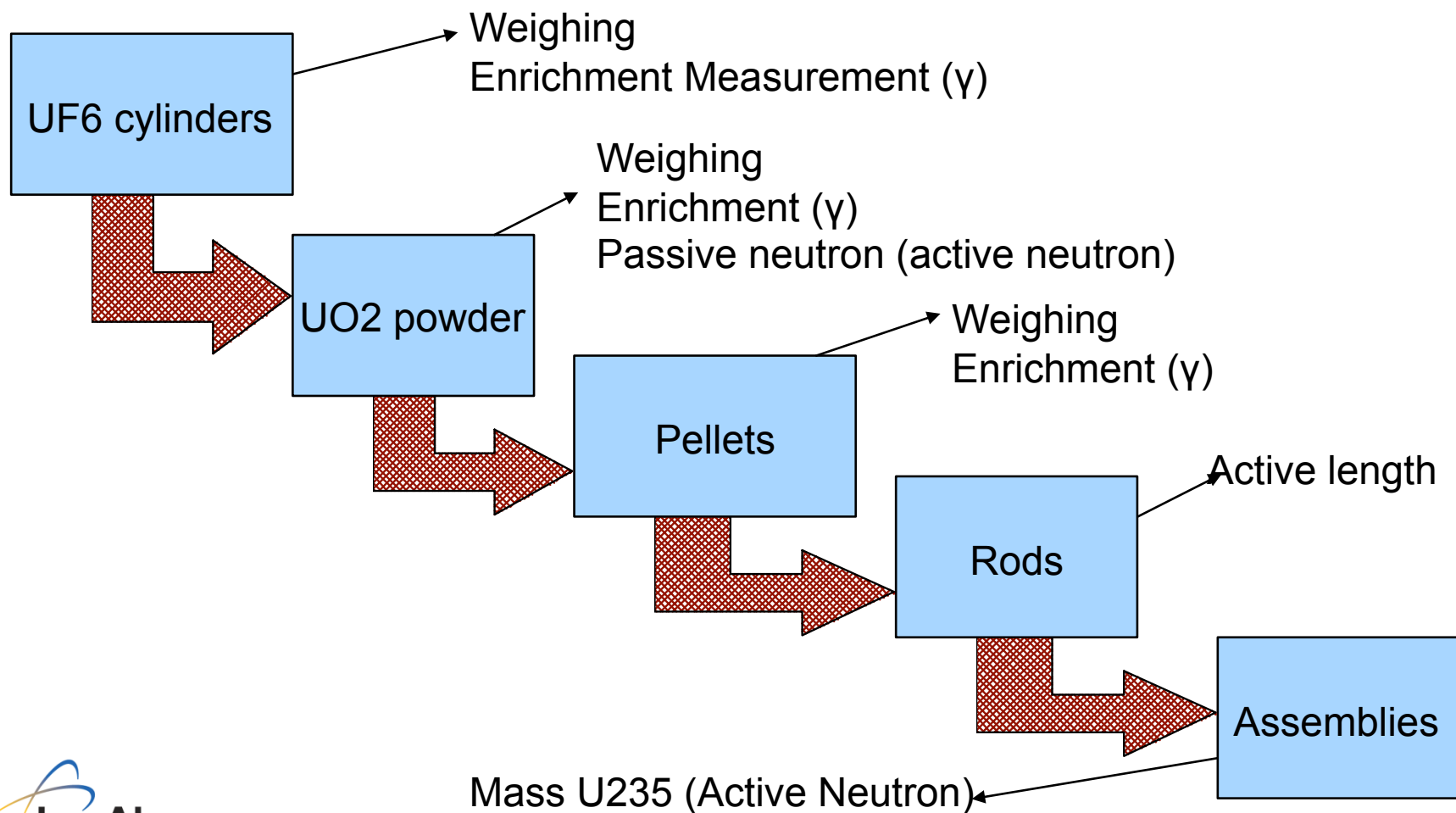


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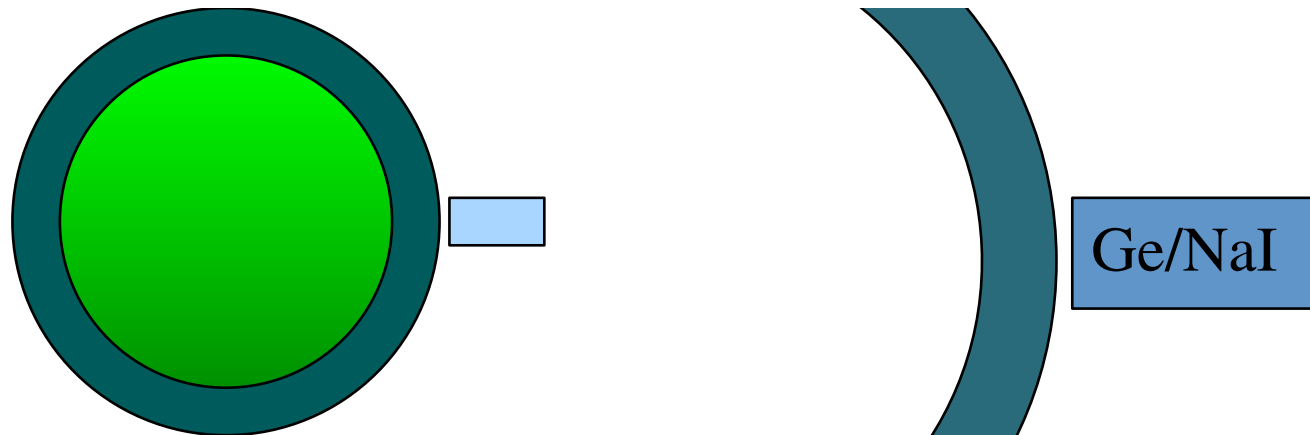
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Safeguards Measurements



Enrichment Verification Measurements of UF₆ Cylinders

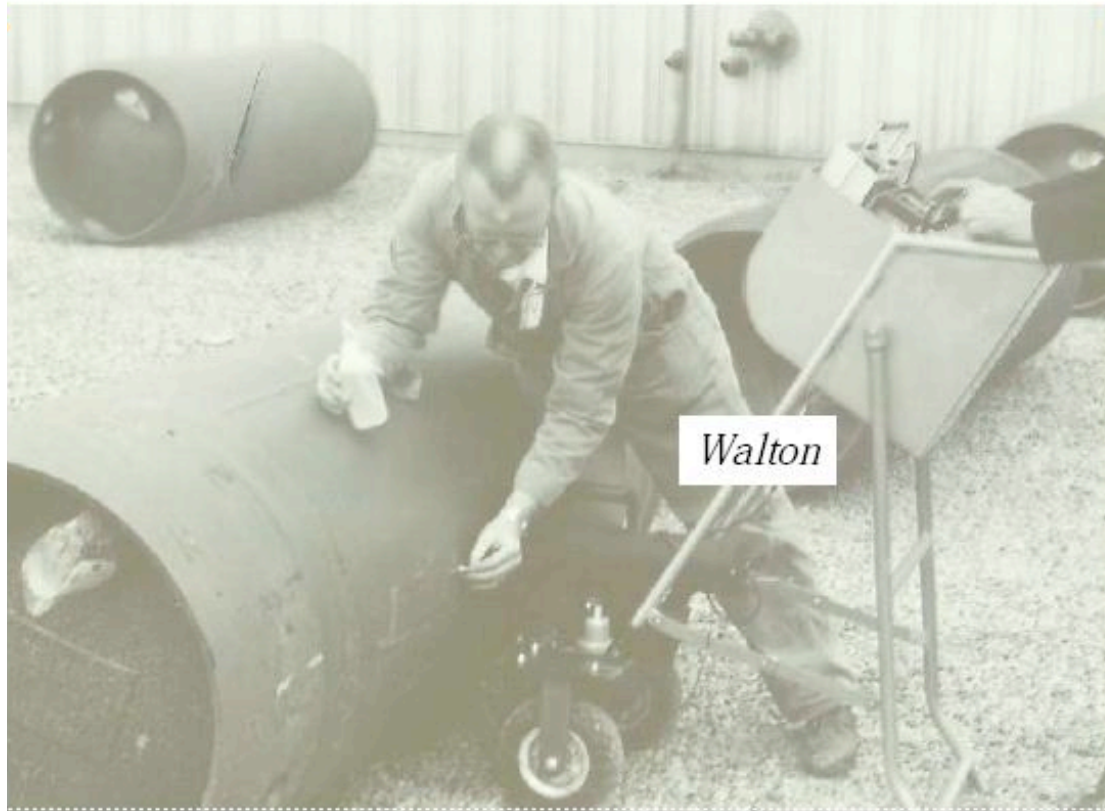
- Measure 186keV line from ²³⁵U assuming infinite thickness of U
- Correct for thickness of container (ultrasonic thickness gauge)
- High resolution to prevent interference from ²²⁸Th peak



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Early In-Field Measurements

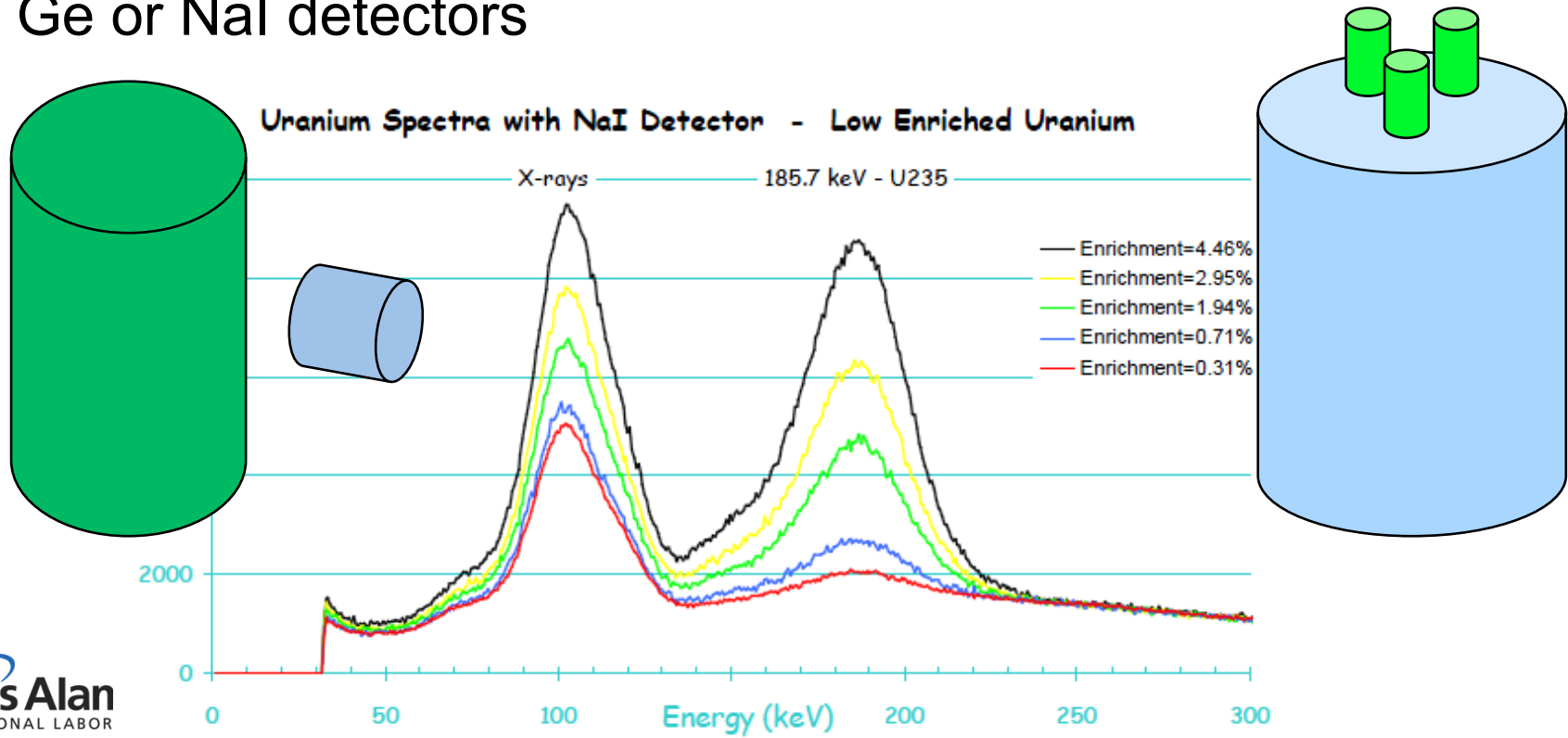
1969 Gamma-ray Enrichment Meter at ORNL



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Enrichment Verification Measurements of UO_2 Powder and Pellets

- Gamma – enrichment from 186 keV line of ^{235}U – calibration
- Ge or NaI detectors



Verification Measurements of UO₂ Powder

- Passive Neutron Measurements
 - ²³⁸U spontaneous fission emission
 - + enrichment
- Active Neutron Measurement
 - PHONID 60 keV neutron source (below ²³⁸U fission threshold with fast neutron detection (⁴He))

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Verification Measurements of Fuel Rods

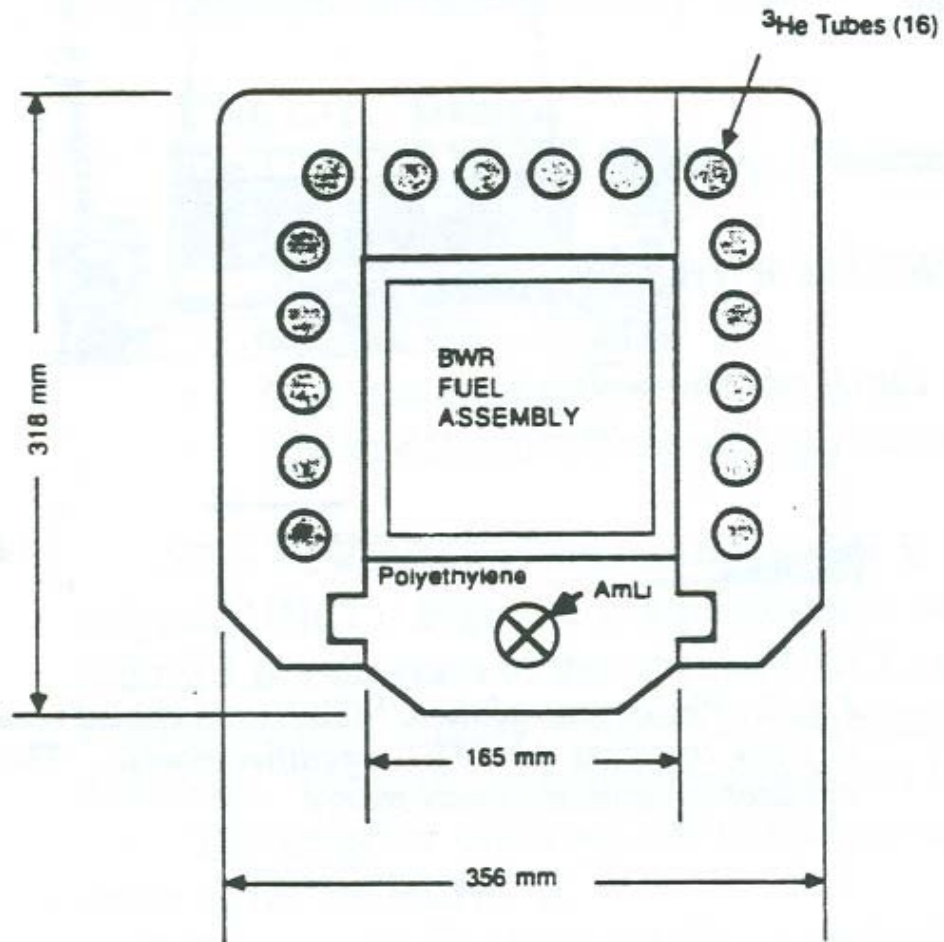


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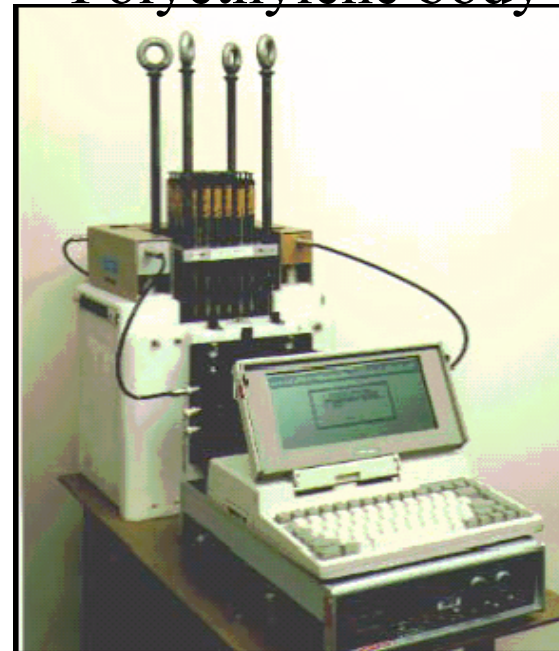
Verification Measurements of Assemblies

- Use a neutron coincidence collar UNCL – active neutron
- AmLi neutrons are (alpha,n) neutrons – no neutron coincidences from the source
- AmLi neutrons induce fissions in ^{235}U and not ^{238}U

UNCL –Uranium Neutron Collar

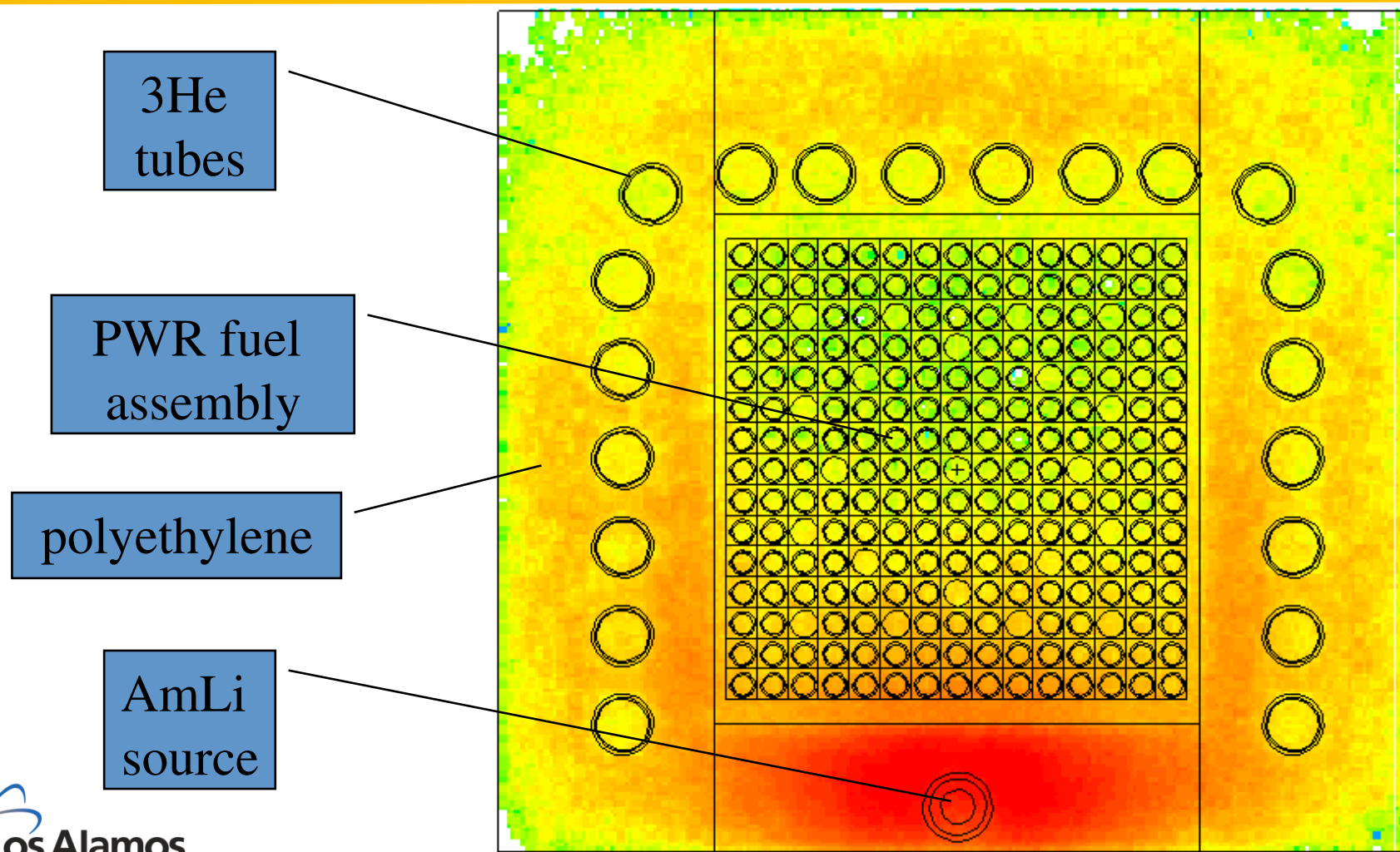


- 16 ^3He tubes
- Lift-out door
- Uses one AmLi source
- Polyethylene body



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Neutron Collar (PWR)



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UNCL Response

$$R = (k_0 k_1 k_2 k_3 k_4 k_5) R_M$$

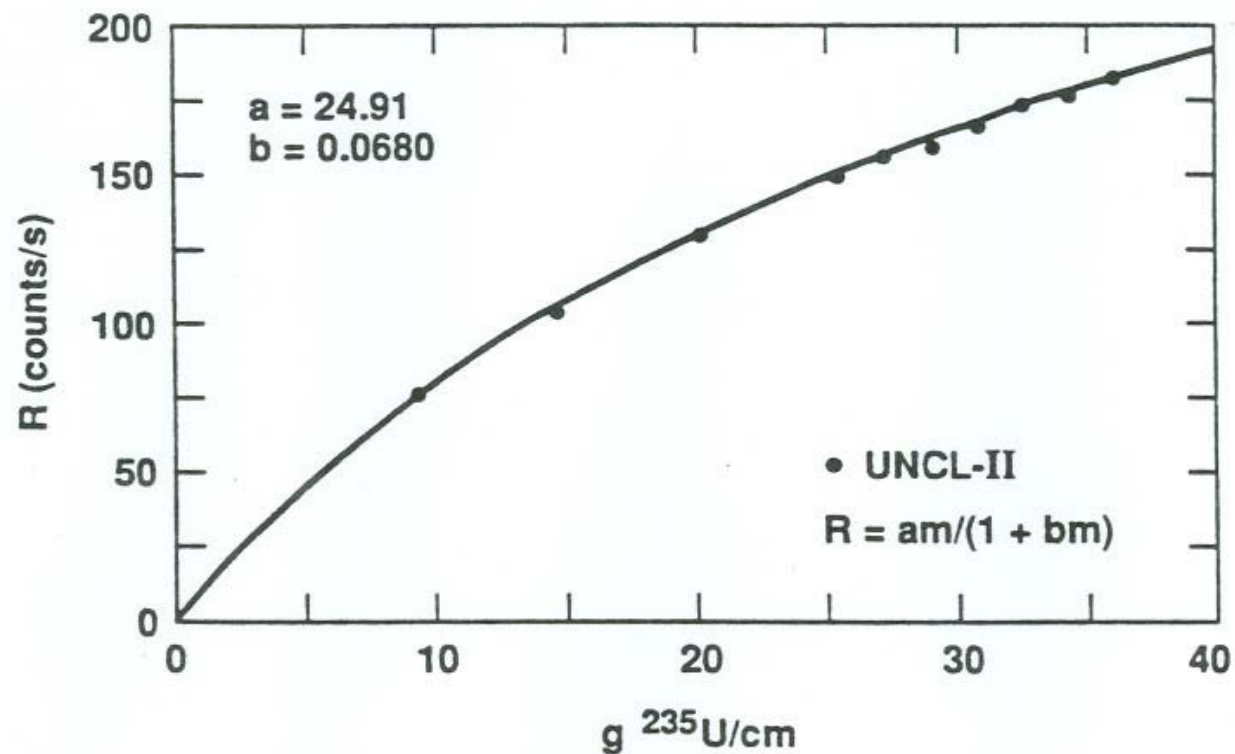
- k_0 – AmLi source strength
- k_1 – Normalization
- k_2 – Detector efficiency
- k_3 – Burnable poison
- k_4 – Heavy metal loading
- k_5 – Other conditions
- R_M – Measured response

By adjusting the measured response we can use the absolute calibration curves for all collar detectors.

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UNCL calibration curve

Calibration curve for BWR fuel (thermal mode)



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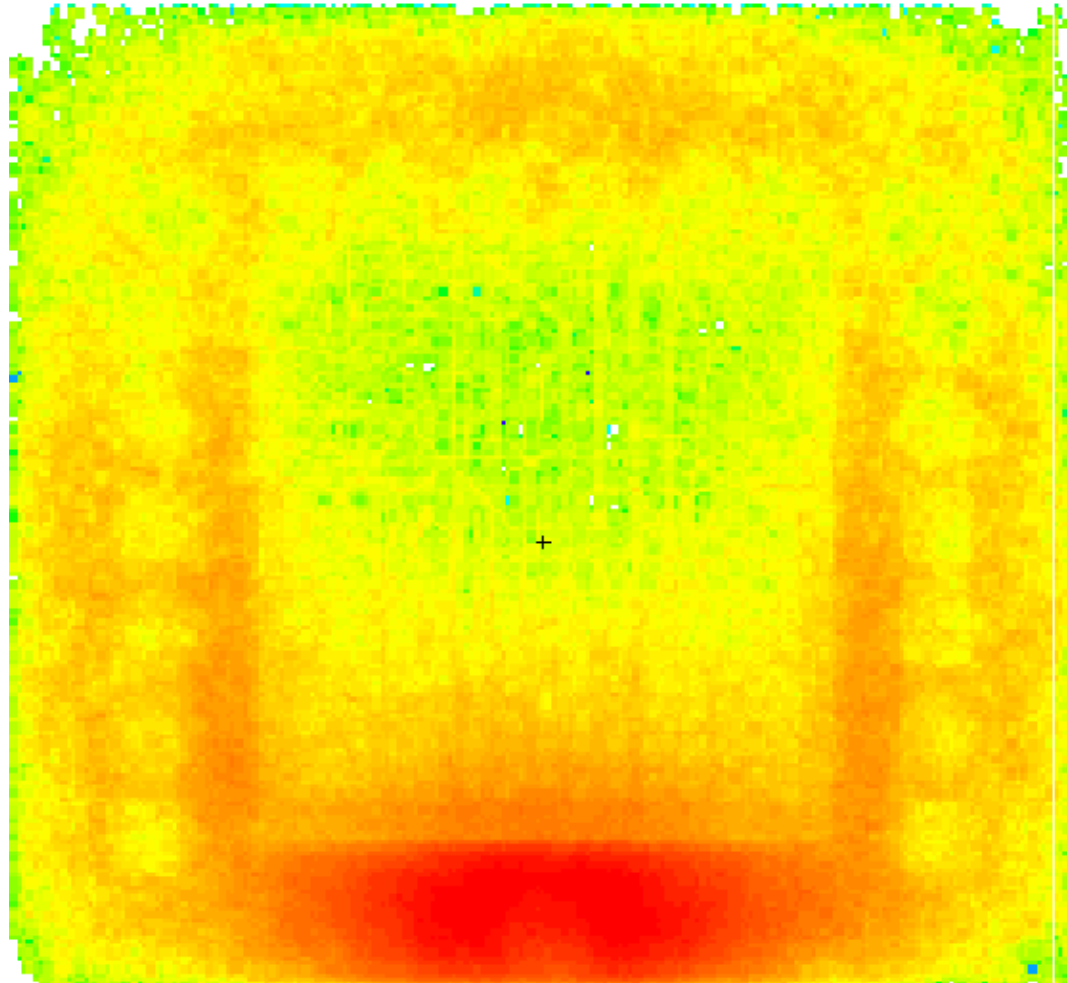
Burnable Poisons

- Correction based on number of poison rods (and type)
- Correction is small for Cd liner mode - measurement time ~1 hour)
- Correction larger for Thermal mode (no Cd liners) - measurement time ~10 mins
- (Measurements with and without Cd can verify burnable poison declaration)

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Sample Interrogation

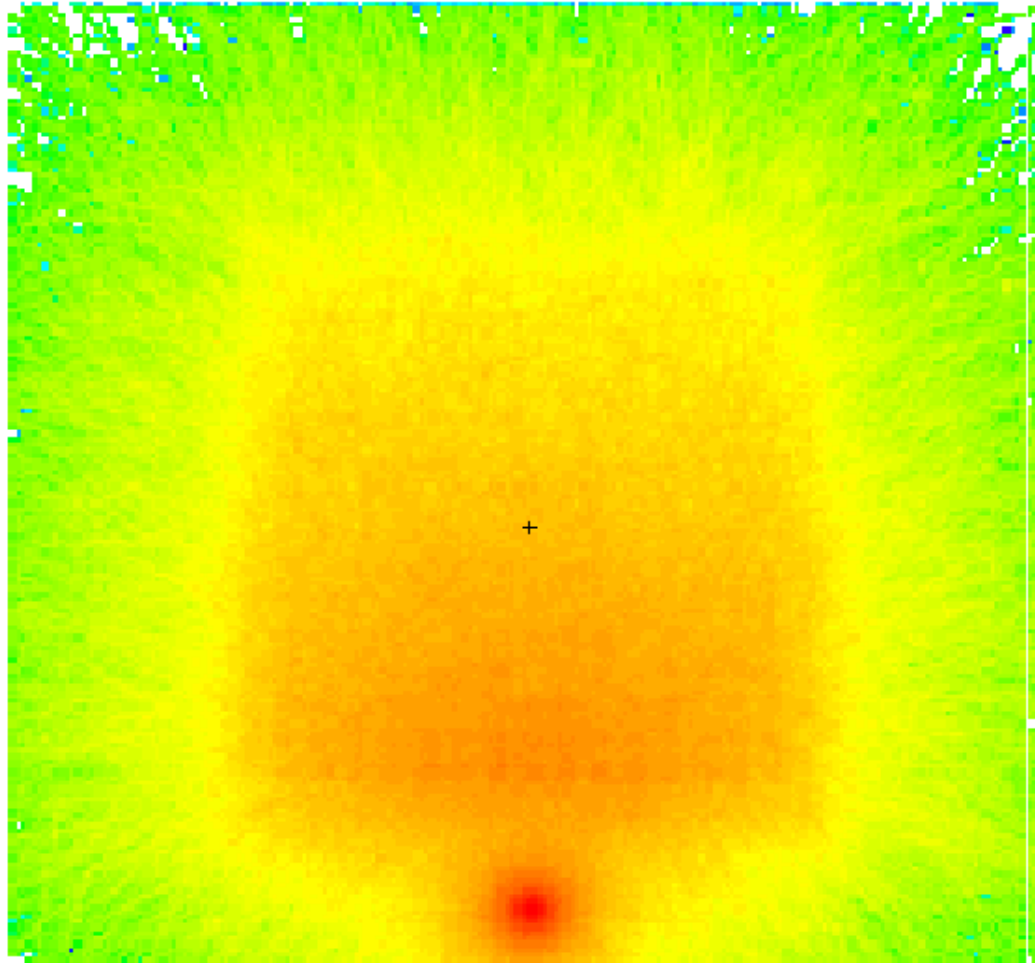
- Thermal Flux -



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Sample Interrogation

- Flux >1 MeV-

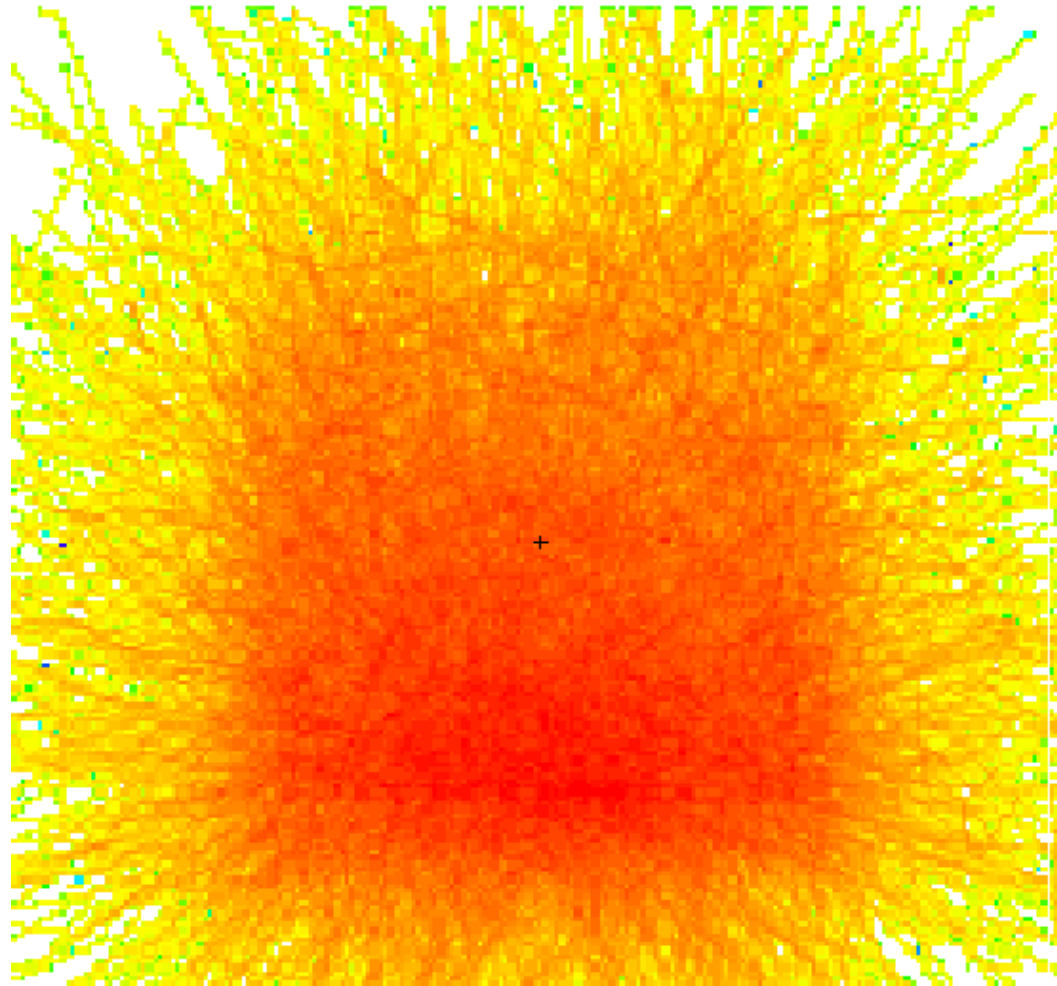


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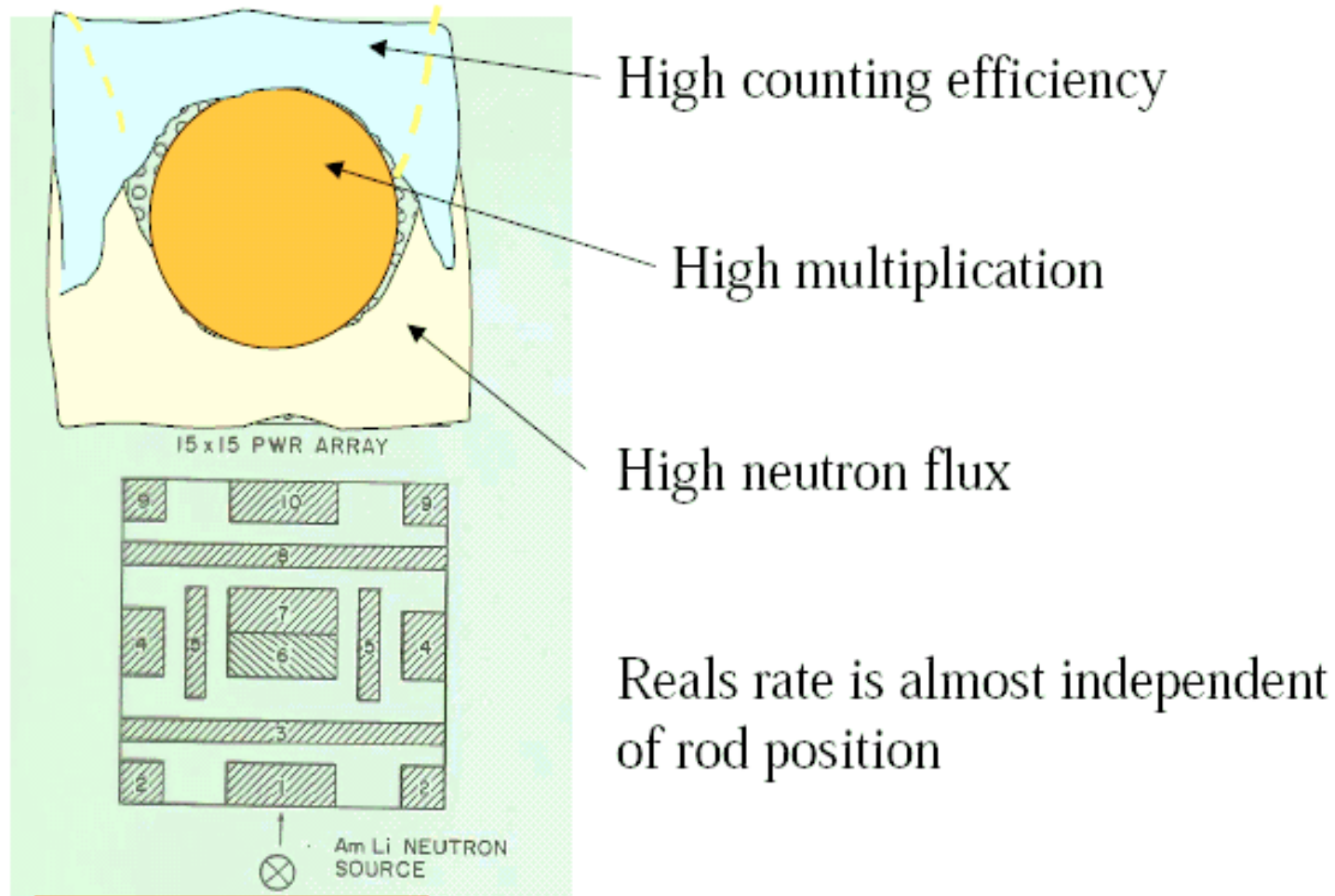
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Sample Interrogation

- Flux > 2 MeV -



UNCL – response with position



Summary

- LEU is relatively low “value”
- Need PIV + verification of shipments and receipts
- NDA measurements of UF_6 cylinders, UO_2 powder and pellets and finished fuel assemblies

